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arrived at by this astronomer cannot be permitted to guide us in the present question.

Fallows had also very inadequate instruments to work with, consequently much weight cannot be attached to his measures; but, so far as they go, they suggest a *very* considerably greater elongation in the south-preceding direction than Dr. Elkin's orbit would allow, in fact a greater one than even now seems to be warranted by the circumstances I have dwelt on above. I may mention that the measures of Rümker and Dunlop also indicate that the orbit runs out tolerably far in the south-preceding direction.

On the whole I cannot but think it highly probable that the apparent orbit is considerably larger than has been supposed, and that the period may embrace some 86 or 87 years.

Hampstead:
1884, *Nov.* 12.

Note on Stellar Photography. By A. A. Common.

Photography, as a means of charting the stars in a rapid and most accurate manner, is now, through the introduction of the gelatine dry plate, likely to come into extensive use, if it does not entirely supersede the old method of eye observation of each separate star. Its power to picture the stars in their proper relative positions and magnitudes in a way that is free from personal error, and under conditions that can be easily and certainly reproduced at any future time, renders the work done in this way so valuable in many investigations, that it is hardly possible to properly estimate it, while the much greater amount of work that can be done will render it still more valuable.

As is well known, photographs of double stars and clusters of stars have been made many years ago, but from the difficulties in connection with the use of the wet plate process then generally employed, the results were not very great in comparison with the trouble that was required. A negative of the *Pleiades*, now in possession of this Society, by Rutherfurd, is perhaps one of the best photographs by this old process.

Many other photographs have been taken from time to time in this manner, but it is but recently that the practicability of taking large fields with comparatively small apertures has been shown.

Attention was, I believe, first drawn to this by the remarkable photographs of the great comet of 1882 that were taken at the Cape and sent home by Dr. Gill. Through the kindness of Dr. Huggins I saw one of these photographs very soon after it came to England, and I must say that I was extremely surprised at the number of stars that were shown. It is true that they were large and ill-defined, particularly at the edge of the plate, but

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there they were, and that was the great thing, considering that only an ordinary portrait lens had been used.

I had in 1879, in the course of experiments with the 3-foot telescope, taken pictures of the *Pleiades* with $1\frac{1}{2}$ minutes' exposure, using the gelatine dry plates then being introduced, that showed stars of the 8th and 9th magnitude.

These comet photographs, however, opened out a new way that I was not slow to follow. I was then (in 1882) working at the photographs of the nebula in *Orion*, devoting every fine night to that purpose. One evening when thus working I attached a small camera to the mounting of the large telescope, and with a lens of about $\frac{3}{8}$-inch aperture I exposed a plate for twenty minutes—the time I was then giving to the plate in the large telescope. The result of this first experiment with small aperture was most surprising. The stars that form the figure of *Orion* were there, and stars in the centre of the field to about the 9th magnitude, and a portion of the nebula itself. The stars near the edge were a little oval, but not very objectionably so. I did nothing further just then, but determined to follow the matter up by more experiments. For this purpose I completed a 6-inch refractor by February 1883, with a mounting specially made to carry cameras on the declination axis; and through the kindness of Messrs. Ross, the opticians, I tried almost every kind of lens that is made for photography. Judging by the picture already mentioned, I had contemplated as possible a field of at least 10° without altering the perfectly round shape of the stars, or losing too much light at the edge of the field; but the results of many experiments with symmetrical, rapid symmetrical, landscape, portrait, and other lenses was not favourable. Some gave better fields than others, but the amount of astigmatism and loss of light away from the centre was greater than with the first small lens. I came to the conclusion that with the best ordinary lens it would not be safe to rely on more than 4° or 5° of the centre of the field for freedom from astigmatism and equality of illumination. Messrs. Ross told me they could make a special lens that would be very much better, but I have not yet learnt that anything has been done by them.

I have brought here to-night a picture of part of *Orion* taken during these experiments; it is cut out of the centre of a larger plate, but it shows what can be done with such lenses as those I have named. A comparison with Argelander's Atlas shows that some of his 9th and 10th mag. stars are shown, and that in several cases there is considerable difference in positions and magnitudes. I have also brought a picture of the *Pleiades* taken with a lens of 4-inch aperture and about 2-feet focus, and one of the plates taken with the very small lens. In using photography, the first thing would naturally be work in some plan that would allow a series of pictures to be taken of the whole heavens on as large a scale as it could be done on in a reasonable time; for this purpose the lens appears the most suitable, leaving the reflector

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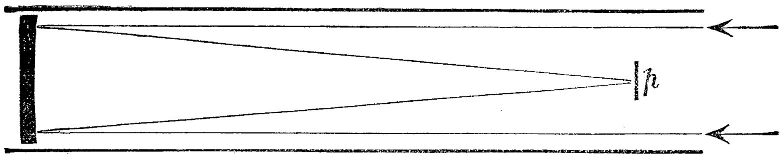
for large pictures of objects of interest, such as nebulæ, clusters, &c. The difficulty with the lens has, however, led me to consider how the reflector might be utilised; the ordinary arrangement does not lend itself to large fields, but from various experiments I have reason to think that it *is* possible to use the reflector for this purpose. The choice seems to me to be practically between three different arrangements: the first is when the sensitive plate is placed in the principal focus, directly in front of the large mirror; the second is a modification of the Cassegrain telescope (amounting almost to a new form) made by increasing the size of the small mirror to one half or even more of the diameter of the large mirror; the third is a form of telescope invented in Germany, and not much known here—it is called, I believe, the "Brachy" telescope, and is on the same plan as the Cassegrain, but the small mirror is placed outside of the tube, so to speak, and the mirrors are used obliquely. For the purpose of making the different arrangements more easily understood, I have given an outline sketch of each that will show at once the distinctive differences between them. The first arrangement has simplicity to recommend it, and as a large telescope I can imagine nothing better. There is only one surface, so that the greatest possible amount of light is used effec-

1.



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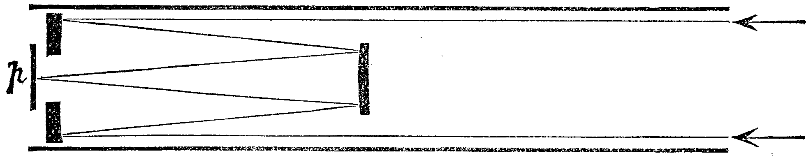

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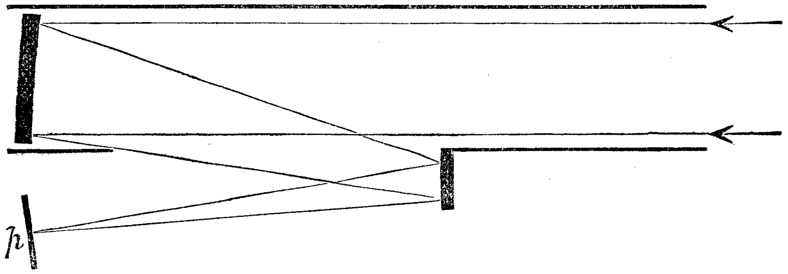

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tively, and it is symmetrical; for this work, however, where flatness of field is necessary, I do not think it can be so good as either of the other forms. The second arrangement is peculiar, and with a mirror of 5-foot aperture the supports of such a second mirror might be difficult; on the other hand, the loss of reflecting surface can be made up by a trifling increase of diameter in comparison with other forms. The connection between the mirrors can be made very rigid as they are so near, the surfaces can be wrought to suit each other and to give a flat field in addition, all is symmetrical, and that is important, and the plate is in a convenient place for exposure under examination, and is quite protected by the smaller mirror from the direct light of the sky.

The largest instrument of this kind that I have tried has a concave mirror of $9\frac{1}{2}$ inches, and a smaller mirror of $4\frac{1}{2}$ inches diameter; the focal length of large mirror is 43 inches. This instrument, roughly mounted in a wooden box, and attached to the 6-inch telescope, forms a photographic telescope that will give a picture of an 11 mag. star in thirty minutes under very unfavourable circumstances. The field of view is 3° only, as the hole that I cut in the large concave is not larger, but as far as it goes it is good. Altogether the arrangement has been more satisfactory than I expected, and I intend to try larger sizes to see if any new features become developed.

The third arrangement I have not tried with photography, but it is quite possible that it may be the best for this purpose. I have tried it on artificial stars, and the way in which the second mirror corrects the astigmatism due to the oblique position of the large one is most remarkable. I cannot find very much information about it, though, no doubt, some exists. I mention it and the other form in the hope that some one may make some trials of it for photography, as it is important to have all the information possible as to the best kind of telescope for this purpose, and this can be best done by many independent experiments. It appears to me that the aim ought to be the production of photographic charts made up of separate fields of 4°, 5°, or 6°, or even more if it be possible, on a scale at least twice that of Argelander's Atlas, and including stars of the 12th magnitude, and this with a moderate exposure.

I believe this, and more than this, to be now possible, but it is necessary that the best way to do it should be clearly shown.

Note on a Method of giving Long Exposures in Astronomical Photography. By A. A. Common.

In exposing a sensitive plate for a long time the image is liable to shift, from the driving clock not keeping pace with the diurnal motion, from change in the apparent place of the object due to refraction, from change in the position of the focal plane